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14. **ABSTRACT**

This thesis examines the increasing capability and proliferation of land attack cruise missiles (LACMs) within the context of the changing geopolitical environment. The research analyzes the current state of NORAD's homeland cruise missile defense apparatus with respect to its organization and technical capability. The principle argument is that land attack cruise missiles are becoming increasingly lethal, accurate, stealthy, prolific, easy to employ, and difficult to detect. The United States and Canada lack a sufficiently robust cruise missile defense system capable of defending the homeland against a wave of LACMs. This thesis recommends the United States empower a single defense organization to lead a binational team to develop, acquire, and deploy a comprehensive cruise missile defense system within NORAD. It asserts that emerging directed energy weapons should be integrated with existing kinetic systems to create a layered cruise missile defense for the homeland.

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NATIONAL DEFENSE UNIVERSITY

JOINT FORCES STAFF COLLEGE

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WHAT TO DO ABOUT THAT PACK OF WOLVES AT THE DOOR: A BINATIONAL ORGANIZATION AND ACQUISITIONS APPROACH TO HOMELAND CRUISE MISSILE DEFENSE

by

Clayton J. Percle

Lieutenant Colonel, United States Air Force

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A paper submitted to the Faculty of the Joint Advanced Warfighting School in partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning and Strategy. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense.

This paper is entirely my own work except as documented in footnotes.

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Abstract

This thesis examines the increasing capability and proliferation of land attack cruise missiles (LACMs) within the context of the changing geopolitical environment. The research analyzes the current state of NORAD's homeland cruise missile defense apparatus with respect to its organization and technical capability. The principal argument is that land attack cruise missiles are becoming increasingly lethal, accurate, stealthy, prolific, easy to employ, and difficult to detect. The United States and Canada lack a sufficiently robust cruise missile defense system capable of defending the homeland against a wave of LACMs.

This thesis recommends the United States empower a single defense organization to lead a binational team to develop, acquire, and deploy a comprehensive cruise missile defense system within NORAD. In the meantime, USNORTHCOM/NORAD should continue to leverage existing systems to mitigate gaps in cruise missile defense. The President should expand the role of the Missile Defense Agency (MDA) to include cruise missile defense. Congress should provide funding and oversight for the MDA's increased role. The MDA should take the lead of a binational acquisitions program which leverages existing commercial and military technologies and issues a request for proposal for entirely new systems.

The MDA and NORAD should field a layered cruise missile defense system which utilizes robust early warning and target detection sensors which are integrated into a streamlined command and control network. The layered engagement systems should be comprised of directed energy weapons such as high-power microwave, and high-energy laser in the approaches, as well as legacy kinetic systems such as manned fighters and surface-to-air missiles near high-value targets. If the United States and Canada fail to develop and field a comprehensive defensive system for NORAD, the homeland will remain vulnerable to attack from cruise missiles.

Dedication

This research is dedicated to my children and unborn grandchildren…may they never know the horrors of war.

Acknowledgements

This work would not have been possible without the invaluable guidance and insight of Dr. Pavelec and Col Therrien. A special thanks is owed to Mr. Frank Kenlon, of the Defense Acquisitions University, who took on the challenge of trying to teach a crusty fighter pilot about acquisitions. But I owe a very special debt of gratitude to my loving bride, who helped me distill clarity from chaos. Thank you darling.

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I. Introduction

Background of the Problem

As the coalition waged its offensive campaign against Iraq in March of 2003, five land attack cruise missiles (LACMs) skimmed over the desert toward their targets. The defensive radar operators failed to detect the incoming low-altitude missiles and never stood a chance of engaging them. To the dismay of US forces, it was *Iraq* who had fired these missiles against the coalition. The hunter had become the prey. This little-known engagement signaled the first time an adversary had targeted US forces with LACMs.

Although the United States and Russia have enjoyed a largely uncontested duopoly on cruise missile employment, these increasingly accurate and lethal systems have proliferated widely throughout the world. While the United States and its near-peer competitors have focused their non-proliferation treaties, missile defense technologies, research and development (R&D), and acquisitions on *ballistic* missiles, LACMs have proliferated both figuratively and literally under the radar. Potential adversaries now view LACMs as an asymmetric capability with which they can threaten the US homeland.

Thesis

Land attack cruise missiles are becoming increasingly lethal, accurate, stealthy, prolific, easy to employ, and difficult to detect. The United States and Canada lack a sufficiently robust cruise missile defense system (CMDS) capable of defending the homeland against a wave of LACMs. The US government (USG) must empower a single defense organization to lead a binational team to develop, acquire, and deploy a comprehensive CMDS within NORAD.

Impact

Cruise missiles are capable of carrying conventional, nuclear, biological, radiological, and chemical payloads. They are generally categorized as either LACMs, or anti-ship cruise missiles (ASCMs). This thesis uses the term cruise missile and LACM interchangeably as they are the sole focus of the research. While the threat of a nuclear attack against NORAD remains the most dangerous and existential threat to the United States and Canada, it also remains quite unlikely. This is due largely to mutually assured destruction deterrence theory, and sweeping nonproliferation and arms reduction treaties between nuclear states.[1] However, it is still possible for a belligerent nation to coerce the United States and Canada with the threat of conventional cruise missile strikes.

If NORAD is unable to defend the United States and Canada against a wave cruise missile strike, China or Russia may view this an attractive and measured option aimed at affecting US policy. For instance, if China chose to invade Taiwan the United States would likely respond. Any plan to defend Taiwan would require targeting Chinese missile sites on their southeast coast. In order to dissuade US involvement, China could threaten a limited counter-value offensive response against the US Pacific coast with LACMs. In 2010 nearly 50 million people lived in the west-coast states of the continental US alone.[2] If credible, this threat would present a paralyzing political dilemma for USG policy-makers and likely prevent United States involvement.

In addition to the conventional LACM threat, there are non-state actors who may seek to employ cruise missiles as a means for delivering non-nuclear weapons of mass

[1] Bernard Brodie. *The Absolute Weapon: Atomic Power and World Order* (Yale: Harcourt Brace, 1946), 76.
[2] US Census Bureau Report (2010).

destruction (WMDs). The breakup of the former Soviet Union and the proliferation of atomic energy programs make it increasingly likely that non-state actors may acquire low-yield fissile materials. Terrorists could weaponize these fissile materials as so-called dirty bombs and deliver them via makeshift LACMs from offshore container vessels. These hypothetical terrorists could also employ biological or chemical weapons against the United States and Canada by similar means.

Whether from states with conventional LACMs or terrorists employing makeshift cruise missiles, these systems represent a grave threat to the homeland. If the United States and Canada fail to develop a binational CMD solution capable of addressing this threat, NORAD will remain woefully unequipped to counter it. Without such a comprehensive solution, the US and Canadian people, infrastructure, and very way of life will remain vulnerable to attack by any actor with the will and most rudimentary means.

Research Method

This thesis does not intend to solve the problem of CMD for the homeland; rather, it seeks to bound the problem and identify a framework for further research. The thesis focuses at the unclassified level, which prohibits research into the classified capabilities and limitations. It also precludes research or speculation into any classified technology development which the services, industry, or organizations such as the Defense Advanced Research Projects Agency (DARPA) may currently be undertaking.

The primary sources of research include numerous books and journals on the subjects of land-attack cruise missiles, their proliferation, and the state of cruise missile defense capabilities. Although this research will not focus on UAVs or drones, one can

consider them a comparable threat to the homeland. Non-state actors would be the most likely to employ them, but they could be countered similarly to LACMs.

The majority of contemporary literature on cruise missiles and CMD is found in peer-reviewed journals and trade publications. Various Department of Defense (DoD) resources, including personal interviews, also provide valuable insight into the current organizational construct. Furthermore, they contribute to recommendations for an optimum organizational solution as well as the ideal acquisitions approach.

This thesis examines the current geopolitical environment while explaining the state of cruise missile technology and proliferation. It illustrates the urgency of the threat and analyzes the current capability for the United States and Canada to defend against it. The study describes the myriad organizations within industry and government which all possess a piece of the puzzle to solve this complex problem.

The research does highlight some emergent technologies which may be incorporated in the Find, Fix, Track, Target, Engage, and Assess (F2T2EA) kill chain. However, its primary aim is to recommend an organizational model capable of realizing a long-term binational CMD solution between the United States and Canada. Of equal importance, the thesis recommends an optimum acquisitions approach targeting a program of record with Initial Operating Capability (IOC) by 2025.

II. Analysis

Geopolitical Environment

The current geopolitical environment is complex, dynamic, and increasingly dangerous. Since its inception, The United States has flourished with the safety of two vast oceans and relatively friendly neighbors to its north and south. Furthermore, it has enjoyed a largely unchecked hegemony since the fall of the Soviet Union. However, nations such as Russia and China are expanding their regional and global influence. They seek to challenge the status quo while establishing regional hegemony within their spheres of influence. Meanwhile, non-state actors including transnational terrorist organizations seek to counter-balance US primacy by asymmetric means.

Russia

Russia has demonstrated renewed imperial ambitions and increased defense spending, procurement, and capabilities. Russia's involvement in Georgia, Ukraine, and Syria demonstrate this desire for greater influence in world affairs. To this end, Russia has increased its defense procurement by 20 percent from 2014.[1] Furthermore, Russia seeks to achieve a navy and air force capable of global strike and defense against the United States including ships with long-range precision munitions.[2] This further illustrates Russia's desire for increased military power to counter US primacy.

In order to codify the ways and means to this end, Russian President Vladimir Putin signed the "Military Doctrine of the Russian Federation" into law in December, 2014. The doctrine describes Russian military capabilities, their view of the nature and

[1] Stephen J. Blank, "Imperial Ambitions," *World Affairs* Vol. 178, No. 1 (May/June 2015): 68.
[2] Ibid., 70.

characteristics of modern military conflicts, when they would use armed force, and guidelines for the development of armed forces. Of particular interest to the United States, Russia cites the increased power of the North Atlantic Treaty Organization (NATO) as its main external military danger.[3]

In a clear signal to the world that they are willing to back up their doctrine with action, Russia launched 26 Kalibr SS-N-30A LACMs against targets nearly 1,000 nautical miles away in Syria on October 7th, 2015. One US official described this attack as a clear message from Russia that they have this capability and are willing to use it.[4] Although the success of the strike is a matter of debate, it boldly signaled a literal and figurative shot across the bow of US primacy in the region.

China

Although Russia has garnered the most attention in Europe and the Middle East, China has emerged as a significant regional power in the Pacific. They are seeking regional dominance of the South China Sea and have engaged in naval cooperation exercises with Russia to this end. As the United States has checked China's expansion in the Pacific, Moscow has pulled Beijing closer.

In 2012 China and Russia joined in a Pacific exercise which included the simulated launch of cruise missiles. China intended this exercise as a sign to Asia and the United States of their enhanced capabilities.[5] Most recently, China and Russia

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[3] "Military Doctrine of Russian Federation," *Military Technology*, (2015): 191-212.

[4] Christopher Cavas, "Is Caspian Sea Fleet a Game-Changer?," Defense News, October 11, 2015, http://www.defensenews.com/story/defense/naval/ships/2015/10/11/caspian-sea-russia-navy-missiles-attack-strike-military-naval-syria-frigate-corvette-lcs-littoral-combat-ship/73671188.html (accessed November 16, 2015).

[5] Stephen J. Blank, "Russo-Chinese Naval Exercises Reflect Moscow's Delicate Balancing Act in Asia," *Eurasia Daily Monitor* Vol. 9, No. 95 (May 2012): 2.

engaged in another naval exercise in which five Chinese vessels passed within 12 nautical miles of the US Aleutian Islands. China likely made this gesture in defiance of US involvement in the South China Sea and possibly to establish itself as a force in the expanding commercial activity of the Arctic.[6]

Of great concern to the United States, several Asian nations such as China have embraced an offensive doctrine which relies on LACMs. China's exercises demonstrate an effort to actively take the initiative to catch their adversaries off guard. Chinese doctrine refers to LACMs as "trump card" weapons and focuses on saturating "tidal wave" attacks within a narrow timeframe. Therefore, China believes in a 9:1 cost advantage of offensive LACM employment over defending against them.[7]

Perhaps even more troubling is evidence China may plan to use their cruise missiles to hit particular precision targets from unexpected axes.[8] This would further complicate the CMD equation for NORAD. As states such as Russia and China embrace truly offensive war doctrines they may be moving inadvertently closer to a lower threshold between peace and war.

US concerns and non-state actors

The rising power of Russia and China has not gone unnoticed by US military leaders. In his testimony before the Senate Armed Services Committee (SASC), Admiral William E. Gortney, USNORTHCOM and NORAD Commander, described many of the

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[6] Missy Ryan and Dan Lamothe, "Chinese Naval Ships Came Within 12 Nautical Miles of American Soil," *The Washington Post*, September 4, 2015. https://www.washingtonpost.com/world/national-security/chinese-naval-ships-came-within-12-nautical-miles-of-american-soil/2015/09/04/dee5e1b0-5305-11e5-933e-7d06c647a395_story.html (accessed October 7, 2015).

[7] Dennis M. Gormley, *Missile Contagion: Cruise Missile Proliferation and the Threat to International Security* (Annapolis: Naval Institute Press, 2008), 14.

[8] Norman Friedman, "Chinese Tomahawks," *U.S. Naval Institude Proceedings* Vol. 138, No. 9 (September 2012): 88-89.

issues confronting his command. Of particular interest was his description of Russia's increased heavy bomber out-of-area patrols in 2014, greater than in any year since the Cold War. He also described Russia's increased capabilities and interoperability as well as the prospect of NORAD's increased vulnerability to cruise missile threats.

Admiral Gortney expressed his concern over the proliferation of cruise missiles amongst near-peer competitors, providing a nexus between the rising power of Russia and China and their capability to strike the United States and its allies:

> We remain concerned with the development of conventional cruise missiles that could provide near peer adversaries with options to strike the United States without the perceived risk of retaliation of a nuclear exchange. For over forty years we have enjoyed an unchallenged ability to employ precision conventional cruise missiles at low altitudes evading radar detection. However, the emerging capability of near peers to generate similar long-range strike effects could complicate our decision-making and limit our options in a crisis.[9]

Although one could argue that an attack by Russia or China on the United States is far from iminent, it is a threat military leaders must take seriously. As one general officer remarked to the Joint Forces Staff College in 2015, "My job is to see the glass as half-empty."[10] His sentiments reflect the necessity for the US military to maintain its advantage in capability, as the intentions of other nations can change quickly.

Of equal concern, there are myriad non-state actors who seek to kill western citizens on their own soil. The recent attacks by terrorists in Europe and the United States demonstrate these particular extremists' willingness to export terror on a large scale. As the USG tightens its borders and domestic security, it becomes more likely a

[9] Admiral William E. Gortney, "Statement of Commander, USNORTHCOM and NORAD before the SASC," *Senate Armed Services Committee* (March 2015): 3-11.
[10] Quoted with non-attribution in follow-up to remarks that Russia was an existential threat to the United States.

rogue actor would use assymetric technologies such as rudimentary cruise missiles. These threats would allow them to employ WMD against the homeland outside US and Canadian borders with relative impunity.

State of Threat Cruise Missile Proliferation and Capabilities

Background

When Hitler began employing his V-1 Buzz Bomb against London, it was the first the world had seen of such a weapon. It could fly autonomously across the English Channel and deliver its high-explosive payload to England. Although it was crude and inaccurate, the V-1 effectively struck terror in the hearts of the British population. However, it was the V-2 rocket which captured the imagination of engineers and militaries around the world, ushering in the ballistic missile race.

It was not until the 1970s that the United States fielded its own cruise missile, the Tomahawk. Since then, the United States and Russia have cornered the market in cruise missile technology. For decades the United States has relied on LACMs as its primary long-range deep strike weapon, while it has remained largely unthreatened by adversary LACMs. This standoff weapon has provided an attractive option to US presidents who wish to project power without putting American lives in jeopardy. However, cruise missile technology is no longer the privileged tool of the world's superpowers.

Cruise missile proliferation

Ironically, the USG's own quest for ballistic missile defense (BMD) created the second-order effect of hastening cruise missile proliferation. During the Cold War the United States invested heavily in BMD with little regard for CMD. Systems such as the US Army Patriot missile system were developed primarily for BMD. Therefore,

numerous countries have sought cruise missiles as a relatively low-cost alternative which provides an asymmetric advantage against the United States.

To explain this epidemic, deterrence analyst Dennis Gormley claims there are three factors which affect the proliferation of LACMs. These factors are the importance of access to specialized knowledge, narrative messages about reasons for acquiring cruise missiles, and norms of state behavior relating to nonproliferation policy and defense doctrine as it applies to acquisition behavior.[11]

In spite of the broad proliferation of LACMs amongst nation states, there does not appear to be evidence that non-state actors will easily acquire LACMs. Gormley dismisses the commonly-held reductionist view that globalization causes scientific knowledge to spread steadily, allowing technology to be easily weaponized. For this reason, non-state actors will not acquire the capability to produce and employ advanced LACMs as easily or rapidly as some may allege.[12] Nonetheless, these non-state actors are more likely to acquire lower-technology delivery systems with similar capabilities. The United States and Canada simply cannot ignore this asymmetric threat.

A 2008 report for the Defense Threat Reduction Agency lends further credence to the threat of LACMs. The report clearly illustrates how state and non-state actors may most effectively achieve their objectives through the use of these weapons. It claims cruise missiles may be attractive to both state and non-state actors who face an operational obstacle which would otherwise preclude them from delivering their

[11] Gormley, *Missile Contagion*, 76.
[12] Ibid.

payload.[13] This report reinforces the vulnerability posed by these threats and the likelihood belligerents would use them against the United States and Canada.

While LACMs are unlikely to be employed widely by non-state actors, they have proliferated vastly amongst nation-states in this century. Many nations now employ numerous LACM systems which are becoming relatively inexpensive, accurate, low observable, and compatible with various platforms. Perhaps of greatest concern, belligerents can arm these LACMs with WMD and launch them from makeshift container ships scattered offshore of the United States and Canada while avoiding detection.

Russia is at the forefront of eastern LACM development and proliferation. Russia's aforementioned employment of LACMs in Syria illustrates their ability to launch LACMs from relatively smaller and more numerous surface vessels.[14] Russia is also equipping its submarine fleet with the new Klub-S cruise missile, capable of delivering a 480kg warhead up to 148 nautical miles.[15] These capabilities vastly complicate the problem of defending against such widely dispersed LACM platforms.

Perhaps most concerning is the breadth with which Russia is exporting LACM technologies to potential US adversaries. There is compeling evidence Iran and China obtained curise missile technology from Russia in the early 2000s. This amounts to one of the most serious violations of the Missile Technology Control Regime (MTCR), which was established to prevent proliferation of such technologies.[16]

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[13] Brian Jackson, David Frelinger, and Michael Lostumbo, *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles* (Santa Monica: RAND Corporation, 2008), 2-26.
[14] Cavas.
[15] Luca Peruzzi, "SLCMS: Weapon of Choice for Deep Strike," *Armada International* Vol. 36, No. 5 (May 2012): 20-31.
[16] Guy Martin, "Cruise Missiles in the Asia-Pacific Region," *Defence Review Asia* Vol. 6, No. 3 (2012): 18-21.

Due to this and other violations of the MTCR, over a dozen Asian nations have cruise missiles and many posess indigenous production capabilities. Some of the most notable include India, Pakistan, China, Taiwan, Japan, South Korea, and Australia. China has demonstrated the most pronounced affinity for cruise missiles, which stems from its previous lack of aircraft capable of penetrating advanced air defences.[17] For this reason, China is much more likely to utilize LACMs as their primary means of offensive strike.

Threat cruise missile capabilities

Since acquiring their technology from Russia, China and Iran have fostered robust indigenous LACM technological capacity. They developed their own engines, making the DH-10 and Soumar cruise missiles possible. Of note, the DH-10 can cruise between Mach 0.5-0.7 for up to three hours and deliver a 770-pound warhead over 1,550 miles. Like Russia, China can employ the DH-10 from numerous air, sea, and land-based platforms.[18] With such a system, China can strike US targets as far inland as NORAD headquarters in Cheyenne Mountain, Coloardo, giving credence to Admiral Gortney's aforementioned concerns.

With systems such as the DH-10, China is seeking to acquire an asymmetric "assassin's mace" which could overwhelm a superior adversary such as the United States.[19] China is focusing their military modernization on building modern ground, naval, air, and missile forces capable of fighting and winning local wars under what they

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[17] Ibid.
[18] David Eshel, "Chinese, Iranian Cruise Missiles Show Common Russian Heritage," *Aerospace Daily & Defense Report* Vol. 251, No. 58 (March 2015): 5.
[19] Dennis Gormley, Andrew Erickson, and Jing-Dong Yuan, "A Potent Vector," *JFQ: Joint Force Quarterly* No. 75 (4th Quarter 2014): 99.

call "informationized" conditions. This represents a reliance on information technology in all aspects of military operations. A crucial element of the PLA's investment is the development of LACMs on a range of ground, air, and naval platforms.[20]

China would likely use its naval platforms to overwhelm defenses in a massive attack because they are unable to reload at sea. China trains primarily to mixed employment of ballistic and cruise missiles, targeting the latter against command and control nodes, airfield hangars, and logistics facilities.[21] Their growing arsenal of cruise missiles and the systems necessary to employ them pose new defense and proliferation challenges for the United States and Canada.

In furtherance of its naval LACM capabilities, China has evolved its indigenous cruise missile development and is attempting to deploy a new destroyer to complement them. The vessel boasts improvements in technology that rival those of the newest destroyers being built for the US Navy. Advances include phased array radars, and improved missiles and launch systems. China utilized a weapons test ship to "navalize" the DH-10/CJ-10 LACMs which will be fielded on their new destroyer.[22] With such advanced surface vessels, China is developing a blue-water naval capability that seeks to rival western powers.

As China continues to expand its naval missile capabilities it is using ships to test advanced weapons systems. China utilizes a handful of designs which aim to validate indigenous and reverse-engineered technologies. In addition to the surface-launched

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[20] Ibid.
[21] Bradley Perrett, "West Pacific Cruise," *Aviation Week & Space Technology* Vol. 176, No. 19 (June 2014): 50-51.
[22] James C. Bussert, "China Destroyer Consolidates Innovations, Other Ship Advances," *Signal* Vol. 68, No. 4 (December 2013): 46-47.

DH-10, China has fielded the HN-2C sea-launched cruise missile (SLCM) and is developing the newer YJ-62 with sub-launch capability.[23] A submarine LACM launch capability poses a significant challenge for the United States to detect potential hostile vessels operating off the coast and below the waves. Overall, China's advances in long-range naval LACMs pose a significant threat to the United States and Canada as they represent the capability to strike deep into the homeland from various axes.

In addition to expanding its naval LACM launch platforms, China is also improving its penetration capabilities through the application of radar and infrared reducing technologies. Notably, the Beijing Institute of Aviation Materials has developed paint-based radar-absorbing materials, neoprene tile radar-absorbing coatings, and form-based radar-absorbing coatings.[24] Low-observable LACMs will make it even more difficult for NORAD defenses to successfully detect and engage them.

As it becomes increasingly difficult for NORAD to detect and target these LACMs, they are becoming increasingly capable at finding and striking their intended targets. These LACMs will be able to detect their targets with the aid of electro-optical seekers data-linked back to the operator, contour mapping, and satellite navigation systems which produce accuracy within 10 meters.[25] If these weapons get through NORAD defenses, they are very likely to strike their targets within the US homeland with deadly accuracy.

As LACM technology advances, they become a significantly more cost-effective weapon than ballistic missiles and manned aircraft. One Air War College study

[23] Peruzzi, 20-31.
[24] Gormley, *Missile Contagion*, 76.
[25] Gormley, Erickson, and Yuan. "A Potent Vector," 102.

concludes that cruise missiles will remain a more cost-effective alternative to manned bombers if cruise missile attrition were 80 percent, and aircraft attrition were 5 percent. Coupled with continued proliferation, this will make cruise missiles the most important and decisive weapons in the twenty-first century.[26] Many growing militaries view this dilemma from a pure cost-benefit standpoint. Cruise missiles have emerged as a significantly more cost-effective alternative to manned attacks, particularly in the light of generally weak CMD capabilities worldwide.

State of US Cruise Missile Defense Organization and Capabilities

The US and Canadian governments are poorly organized and equipped to counter this emergent cruise missile threat to the homeland. Although the United States has invested heavily in BMD organization and acquisition, it has paid woefully little heed to the growing cruise missile threat. Since the Iraq war of 2003, many have repeatedly called for the creation of an organization such as the MDA which would be responsible for the enterprise of CMD. Due in large part to a lack of proper organization and funding, NORAD's CMD capabilities remain insufficient to counter the emergent threat to the homeland.

US cruise missile defense organization

One 2005 report to the US Congress specifically raised the concern of the cruise missile threat to the United States. The report surmised that DoD's CMD programs exist under too many organizations. In response, the US Senate called for the Secretary of Defense to establish a single agent to manage homeland defense against cruise missiles

[26] David J. Nicholls, *Cruise Missiles and Modern War: Strategic and Technological Implications* (Maxwell Air Force Base: Air University, 2000), 11.

and other low altitude threats. Unfortunately, the House version of the Defense Authorization Act for Fiscal Year 2006 failed to include similar provisions.[27] The resulting status quo remains to this day.

Although the Pentagon spends more than $9 billion per year on missile defense systems, little of that investment is specifically focused on countering cruise missiles. While most defensive systems are aimed at ballistic missile threats, cruise missiles are far more accessible and difficult to defeat than ballistic missiles. The defense apparatus is gravely concerned with cruise missiles because they can potentially sneak into blind spots.[28] Although money alone never solved any problem, the US CMD budget is woefully lacking.

Were the US CMD enterprise properly funded, it would still remain federated, fractured, parochial, and ineffective. It does not enjoy the unity of effort and budget afforded BMD through the MDA. A few of the myriad stakeholders include USNORTHCOM/NORAD, the Joint Interagency Missile Defense Organization (JIAMDO), the Office of the Secretary of Defense (OSD), the Army Air and Missile Defense Command (AAMDC), the Joint Functional Component Command for Integrated Missile Defense (JFCC IMD) of Strategic Command (STRATCOM), and the MDA to a lesser degree. While OSD is the ad hoc clearing house for the CMD enterprise, it lacks the charter, manpower, and funding to effect a comprehensive CMD solution comparable to the robust BMD enterprise.[29]

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[27] Andrew Feickert, *Cruise Missile Proliferation* (Washington D.C.: Congressional Research Service, 2005), 6.

[28] Sandra I. Erwin, "Proliferation of Cruise Missiles Sparks Concern About U.S. Air Defenses," *National Defense* Vol. 97, No. 711 (February 2013): 22-23.

[29] From telephonic interview with J8/JIAMDO Action Officer.

Instead, the individual services program, budget, acquire, and field their own independent CMD capabilities. The Air Force, Army, and Navy have all procured systems which serve a service-specific role, while CMD capability is merely an afterthought. The services are simply not motivated to program or budget for systems which can only be employed in support of the homeland CMD mission. The OSD, AAMDC, JFCC IMD, and NORAD are then left to parse together a piecemeal solution.

US cruise missile defense capabilities

Due in part to this federated approach to CMD, there is a growing consensus among scholars and practitioners alike that current CMD capabilities are inadequate. In view of the combined ballistic and cruise missile threat, modern systems do not have the capability to adequately defend against a wave attack. While the United States has dedicated substantial resources toward the development of ballistic missile defenses, it has fallen behind in its capabilities to defend against LACMs.

A US National Air and Space Intelligence Center (NASIC) report claims LACMs will continue to proliferate over the subsequent decade and become increasingly accurate. NASIC also asserts that "US defense systems could be severely stressed by low-flying stealthy cruise missiles that can simultaneously attack a target from several directions." The aforementioned attack from the 2003 Iraq war provides direct evidence of US vulnerability to cruise missile attack. The inability for US defenses to even detect the rudimentary HY-2 Seersucker cruise missiles launched by Iraq is evidence of this vulnerability to even the oldest and slowest cruise missiles.[30]

[30] Feickert, 3.

The United States has been forced to divide its cruise missile defense doctrine into active defense measures, attack operations, passive defense measures, and command, control, communications, computers, and intelligence (C4I). Department of Defense Joint Publication 3-01.5 fails to distinguish between defense against those cruise missiles armed with conventional warheads, and those armed with weapons of mass destruction (WMD). Current point-defense systems such as Patriot have a relatively low probability of kill (Pk) against cruise missiles. Manned fighters are also ill-equipped to shoot down cruise missiles based on required reaction time, and the number of fighters required.[31]

The Air Force employs the AIM-120 Advanced Medium Range Air to Air Missile (AMRAAM), on its F-16, F-15, and F-22 fighters to target cruise missiles. However, the number of aircraft and pilots are limited, as are the number of missiles they are able to carry. Employing manned fighters to counter LACMs also requires significant indications and warning for the fighters to launch, fly to an intercept point, detect, target, and engage the LACMs.[32]

The Navy employs the Standard Missile 3 (SM-3), which is a highly capable system. However, it is designed primarily for fleet-defense and is not ideally suited to target LACMs in protection of the homeland. Furthermore, surface vessels which employ the SM-3 are not plentiful, and are typically deployed at sea in support of contingency operations. The United States would require significant notice to posture surface vessels in a manner which would provide a credible CMD capability.

Likewise, the Army has invested $2 billion in the past 10 years modernizing obsolescent legacy missile defense capabilities but failed to integrate them into the

[31] Nicholls, 24-25.
[32] Ibid.

force.[33] The Army employs the very capable Patriot Advanced Capability 3 (PAC-3) missile system. Although Lockheed Martin has improved the PAC-3 to include more capability against low-altitude LACMs, its primary mission is BMD.

The Army employs the PAC-3 missile in defense of its forces, and of high-value targets at home and abroad as defined by the defended asset list (DAL). However, Patriot batteries do not exist in the numbers necessary to provide complete coverage of the approaches to the homeland. Although they are mobile, they would also require significant advanced indications and warnings to deploy as required.

One Naval Postgraduate School study conducted an extensive analysis of the current US capability to counter cruise missiles. It found the United States has enhanced air defense of critical assets and National Special Security Events (NSSE) by adding static and deployable Ground Based Air Defense (GBAD). However, these methods do not support the air and maritime defense over the broad range of American population centers where critical assets do not exist. Cruise missiles are an inexpensive and effective method for causing limited destruction and are small enough to be transported with little visibility.[34] This makes it exceedingly likely an adversary would be able to strike US or Canadian population centers which are not protected by GBAD.

While the aforementioned systems represent only the engagement portion of the F2T2EA kill chain, the remaining links are equally federated. Each service maintains and operates its own equally diverse radar systems which are tasked with tracking these low-flying LACM threats. In most cases these detection systems are optimized to detect

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[33] Walter L. Sharp, and James Thurman, "U.S. Military Needs Improved Missile Defense Technology," *National Defense* Vol. 98, No. 724 (March 2014): 18.
[34] William M. Dowling, and Javier C. Soria, *Optimizing Ground Based Air Defense in Support of Homeland Defense: The Cruise Missile Threat*. (Monterey: Naval Postgraduate School, 2006), 3-4.

aircraft or ballistic missiles, and are typically ill-equipped to detect and track low-altitude and low-observable cruise missiles.

The United States has developed and fielded systems such as Joint Land-Attack Cruise Missile Elevated Netted Sensor System (JLENS), a series of tethered aerostats equipped with radars to detect cruise missiles. However, these systems do not provide comprehensive detection capability of the approaches to the homeland. There are deficiencies in NORAD's capacity to detect, track, and engage LACMs. However, this research focuses primarily on the LACM engagement capability because it is the most lacking.

Overall, the US and Canadian capability to counter LACMs against the homeland is inadequate. The primary deficiencies include detection of low-flying and low-visibility cruise missiles, and the ability to successfully neutralize large numbers of inbound cruise missiles. The USG also lacks the funding and centralized control necessary to orchestrate a comprehensive CMD capability for NORAD. Admiral Gortney was correct in his testimony to the SASC that "defeating the archer is technically more feasible and affordable than defeating the arrow."[35] However, before US and Canadian forces are able to destroy the proverbial archers, they must be able to defend the homeland against the first quiver of arrows.

Potential Solutions for CMD: Organization, Acquisitions, and Technology

To address deficiencies in its CMD capability, the United States must identify the optimum organizational construct, acquisitions process, and applicable technologies. This research first addresses the organizational construct, which is arguably the most

[35] Gortney, 10.

important yet most challenging obstacle. It then identifies the potential acquisitions options available in the short and long-term. Finally, it highlights some of the most promising emerging technologies which may offer more precise and cost-effective CMD engagement alternatives. The status quo is not an acceptable course of action as it cannot adequately address the challenge of CMD.

Organization

The most fundamental task facing the USG is to define and implement an organizational construct which effectively inculcates unity of effort across the various binational stakeholders. Without a properly chartered, mandated, funded, and manned organization, the United States and Canada will never secure an effective homeland defense against cruise missiles. To that end, the United States may consider adopting one of two organizational approaches; each with its own costs, benefits, and programmatic risks. One alternative is to create an independent Cruise Missile Defense Agency (CMDA), and the other is to expand the role of the existing MDA.

A new and independent Cruise Missile Defense Agency

The United States could create an entirely new organization comparable to the MDA, but given responsibility for the entire CMD enterprise. The President of the United States (POTUS) would have to authorize creation of this CMDA. The US Congress would need to pass legislation to designate its oversight apparatus and sufficiently fund it. In parallel with the MDA, the CMDA's mission would be to develop, test, and field an integrated, layered CMDS to defend the United States, its

deployed forces, allies, and friends against all ranges of enemy cruise missiles in all phases of flight.[36]

The option of creating a CMDA would require a tremendous initial financial investment. Creating an agency with such a scope from scratch would require a substantial budget for facility construction and infrastructure. The operating budget for such an organization would also be robust. A manpower assessment would define requirements for numerous support and bureaucratic positions which may be redundant to those which already exist within the MDA.

Although this option would be fiscally onerous, it does boast some attractive benefits. An agency such as the CMDA could work outside the Joint Capabilities Integration Development System (JCIDS) process as does the MDA. The JCIDS process is the formal DoD procedure of defining requirements and evaluation criteria for future defense programs. The authority to develop and acquire a CMDS outside of the JCIDS process would be highly efficient and allow for a much shorter acquisition timeline.

The CMDA would also enjoy relative independence as an agency equal in status to the MDA. As a standalone agency, the CMDA would have its own seat at the table for programming and budgeting. A team of the brightest CMD experts would comprise the CMDA's initial cadre. This would help avoid the potential trappings of nepotism inherent with creating a new department within an established agency. An entirely new organization would also be free of the institutional inertia that often grips deeply entrenched agencies such as MDA. This would ensure the CMDA was fully focused on

[36] This mission is adapted from the MDA web site. http://www.mda.mil (accessed November 7, 2015).

its objective of establishing a CMDS and properly rewarded all who substantively contributed to this aim.

Although an independent CMDA would certainly be an effective and efficient organizational structure, it would also include significant programmatic risk. The greatest of these risks are political. The current political climate is averse to increasing the scale of government, particularly with respect to defense. There would be a great deal of resistance to creating an entirely new agency with the scope and magnitude of the CMDA. There is considerable doubt that Congress would secure the support necessary to create such an agency.

Furthermore, there is equal political sensitivity to increased defense spending. Although an independent CMDA may be the most robust organizational solution, it is also likely the costliest. There is a high likelihood that either Congress or the President would oppose the increased defense spending necessary to create the CMDA. Without broad political support for the sizable budget necessary, Congress is unlikely to pass legislation which creates a new agency like the CMDA.

Expanding the MDA to include the CMD enterprise

Another option is to add the responsibility for the CMD enterprise to the existing MDA portfolio. This, too, would require POTUS to expand the charter and authorities of the MDA. The agency would need to conduct a thorough manpower study to determine the required number and qualifications of additional personnel. Furthermore, the agency would need to assess the need for new facilities and infrastructure. Congress would have to expand the MDA budget to account for the necessary increase in manning and facilities.

The costs associated with the MDA assuming CMD responsibilities would certainly be significant. However, the cost would likely be substantially less than creating an entirely new organization. The CMD division would benefit from efficiencies found in MDA's established organizational infrastructure. There would be significant cost savings associated with expanding existing capacities rather than establishing entirely new and independent ones. A complete study by the Congressional Budget Office (CBO) would be necessary to more accurately define the cost savings as compared to creating a separate CMDA.

One of the greatest benefits of the MDA assuming responsibility for CMD is leveraging the experience and credibility already enjoyed by the MDA. The MDA is highly proficient at the complex task of integrating myriad governmental and binational stakeholders toward a common goal. They boast a successful record of BMD integration and employment, yet understand the nuanced approach necessary when integrating so many diverse organizations. The MDA could leverage this expertise toward the CMD enterprise. With sufficient budgeting and manpower, the newly-chartered MDA would likely be very efficient at acquiring and deploying a comprehensive CMDS.

Although the MDA has the expertise to solve the CMD problem, there are still risks associated with expanding its charter to do so. Congress would still need the requisite support to expand the authorities and budget of the MDA. Although it would be less costly than creating a new agency, the MDA would still require a significant budget increase in an already fiscally constrained environment.

Perhaps the greatest risk associated with placing CMD within MDA is that of institutional inertia. The MDA has been focused on BMD for its entire existence. It is

comprised of BMD subject matter experts who know very little about CMD. Even if the MDA hires the leading experts in the field of CMD, there is still the chance that they will be relegated to second-class status. To mitigate this possibility, the MDA would have to sincerely commit to the CMD mission and immediately integrate those experts into key leadership positions. Otherwise, the MDA would chance falling prey to organizational nepotism and fail to sufficiently provide for CMD.

Acquisitions

After establishing the ideal organizational construct, the United States must then determine the best acquisitions approach to field a comprehensive CMDS. To make this assessment, one must have a basic understanding of the USG and binational acquisitions process. This aids in illuminating a few approaches which may be suitable for acquiring a CMDS. The study identifies and analyzes the strengths and weaknesses of the various approaches, including a binational program with Canada.

Acquisitions background

The US governmental acquisitions process is comprised of two primary elements. The first is known as Big A. This refers to the requirements and budgeting process which uses JCIDS to identify requirements, and the Planning Programming and Budgeting System (PPBS) for allocating resources and budgeting. The second is known as Little A. This refers to the acquisitions process which uses the Defense Acquisitions System (DAS) for developing new technologies or buying a commercial off-the-shelf (COTS) item.[37]

[37] Moshe Schwartz, *Defense Acquisitions: How DOD Acquires Weapons Systems and Recent Efforts to Reform the Process*. (Washington D.C.: Congressional Research Service, 2014), 2-13.

To establish a fully funded program of record DoD must first fulfill the Big A requirement through one of a few methods. First, and most commonly practiced, one of the service components may submit a JCIDS requirement which must be validated by the Joint Staff. Alternatively, a stakeholder can define a Science and Technology (S&T) requirement for inclusion in the Office of Management and Budget's (OMB's) budgetary S&T priorities. Finally, a combatant command can nominate themselves to the Defense Information Systems Agency (DISA) as the lead for a Joint Capability Technology Demonstration (JCTD).

Once the Big A requirement is fulfilled and approved by the Joint Requirements Oversight Council (JROC), the Little A acquisitions process is set into motion. An acquisitions program office manages the program under leadership of the Program Manager. The process includes various decision points and milestone reviews. The first of these is an Analysis of Alternatives (AOA). This process will determine whether COTS technology exists which will fulfill the requirement, or if the program requires a request for proposal (RFP) to source industry to develop the technology. The acquisitions process continues through engineering, manufacturing development, operational testing, production, deployment, operations, and support.[38]

Requirements and budgeting alternatives for CMD

To date, the services have acquired a patchwork of CMD technologies through the JCIDS process. Each department is responsible for providing localized missile defense and has submitted its own requirements for such systems. These include AMRAAM, SM-3, and PAC-3. The strength of the JCIDS process is that it is the most commonly

[38] Ibid.

used method. The services are intimately familiar with the process and it is perhaps the most tried and true method for single-service acquisitions programs.

Although JCIDS is optimum for single-service acquisitions, it has several weaknesses when used to acquire a multi-service system. If DoD or a combatant commander attempt to force an acquisitions program on an individual service, there is significant risk the program will stall due to changing service priorities. For a long-term acquisitions process the service must include the program in the Future Years Development Program (FYDP), Program Objective Memorandum (POM), and each subsequent budget.

The Medium Extended Air Defense System (MEADS) is one example of DoD initiating a program, but failing to win lasting support from the sponsoring service. In 2009, only five years after the MEADS contract was awarded, the US Army declared it no longer wanted the system. By 2011 the United States chose to terminate funding for MEADS.[39] In the case of multi-service and multi-national systems, the JCIDS process introduces significant programmatic risk.

The S&T requirement is another Big A alternative which may be suited to developing a CMDS. This method is optimized toward research activities which span multiple governmental agencies. The OMB budget proposal for FY17 lists national and homeland security as a priority for S&T budgeting. It specifically identifies investments to counter WMD. Due to the WMD threat posed by cruise missiles, the S&T requirement may prove to be an effective means by which DoD can fulfill the Big A requirement for a comprehensive CMDS.

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[39] Phillip Stewart and Andrea Shalal-Esa, "U.S. to stop funding NATO missile defense program," *Reuters*, February 14, 2011.

Another option is for a combatant command to apply to sponsor a JCTD through DISA. Since USNORTHCOM is responsible for homeland CMD, it would be the most likely sponsor. While JCTDs are usually joint, they can also be combined and interagency. One strength of this method is its efficiency, as it typically results in an interim prototype capability within one to three years. The JCTD process also avoids the risk associated with a JCIDS requirement nominated by a single service. The JCTD option may be well suited for a binational CMDS which spans multiple services, governmental organizations, and two nations. [40]

Acquisitions process alternatives for CMD

Once the CMDS becomes a program of record, the Little A acquisitions process will bring it to Full Operating Capability (FOC). To do so, the AOA must first assess the long-term programmatic costs and benefits of purchasing COTS solutions or submitting an RFP for new technologies. Each of these alternatives have their own associated strengths and weaknesses.

As the thesis will discuss further, the defense industry has already conducted significant R&D toward weapons systems which may facilitate CMD across the F2T2EA spectrum. The advantage of purchasing COTS systems is a potentially significant reduction in cost to the government. COTS systems also tend to be more mature technology which may already have a proven record of employment. These technologies also offer reduced programmatic risk that the system won't meet design specifications.

[40] The source of recommended binational acquisitions alternatives is a telephonic interview with Frank Kenlon, Defense Acquisitions University Professor. September 30, 2015. Mr. Kenlon was the chief negotiator for international agreements on the F-35 program.

However, with solely COTS technology it is unlikely the system would be optimized purely for CMD purposes. Instead, the government would have to settle for systems which are likely optimized for various missions. There are also pitfalls associated with patching various systems together in a coherent and integrated CMDS. It is likely the COTS alternatives would be from numerous vendors, which may make it more difficult to effectively integrate them.

In lieu of a COTS alternative, DoD could submit an RFP to industry to meet the requirements for a comprehensive CMDS. An RFP would facilitate competition within industry and afford the most effective alternatives. This process offers a higher likelihood the CMDS would meet all of DoD's stated requirements. By funding the research, development, and production of a completely new system, DoD also increases the likelihood of successful interoperability.

While the RFP process would ensure a made-to-order CMDS, it would also be more costly. Because this type of system has such a niche capability, the United States and Canada would absorb the entire cost of R&D. The only way to defray this cost would be to sell the system to allies through Foreign Military Sales (FMS), which can be a laborious process even if it is found to be in the best interests of national security. Another downside to this approach is the timeline. Acquiring a CMDS from drawing board to FOC would most certainly take longer than the COTS timeline.

Both the RFP and COTS alternatives possess their own strengths and weaknesses for acquiring a comprehensive CMDS. Another alternative is a hybrid of the two. It would be possible for DoD to leverage existing COTS technologies in conjunction with an RFP to integrate those components into a comprehensive CMDS. Various COTS

components would compose individual nodes of the F2T2EA chain wherever possible, while the RFP would seek to fill gaps in capability. In any case, a thorough AOA will be necessary to define the optimum CMDS acquisitions approach.

Binational acquisitions considerations for CMD

Regardless of the acquisitions approach the USG utilizes, it must also decide whether to pursue a CMDS unilaterally or as part of a binational program with Canada. Both options are characterized by their own inherent costs, benefits, and risks. Generally speaking, unilateral acquisitions programs are simpler endeavors but are much more costly. Conversely, a binational approach would distribute the cost of acquisition but would require intensive negotiations to achieve consensus which would likely extend the procurement timeline. This section elucidates the costs, benefits, and risks of each alternative.

If the USG were to pursue a CMDS acquisitions program unilaterally it would incur all of the cost associated with the program. The overall cost of the program would vary depending on the amount of risk NORAD were willing to assume. Options could vary from a nearly impenetrable CMDS system to one which only provides point-defense for high-value areas. Put simply, the fewer resources put toward the CMDS, the more risk assumed by the NORAD region. Regardless of complexity or acquisitions approach, the USG will likely be constrained by a limited budget for the CMDS. Therefore, if the United States funds the CMDS alone it will undoubtedly incur more risk.

One strength of a unilateral approach is its simplicity. By acquiring the CMDS on its own, the USG would certainly be able to achieve IOC more expeditiously. The USG would have the only input on the specifications and requirements, which would logically

result in a CMDS which better conformed to its needs. This approach would be free of any diplomatic hindrances which have plagued past multinational acquisitions programs such as the Eurofighter and the Joint Strike Fighter (JSF).

Conversely, a binational approach would defray the cost of acquiring a CMDS across the US and Canadian budgets. Presuming the Canadian financial contribution would be additive to that of the United States, this option would yield a more robust CMDS. Another benefit of this approach would be diversity. The binational approach would draw on not only Canada's budget, but on its technological, industrial, and governmental resources. This collaborative approach would potentially yield a more innovative and comprehensive solution. However, foreign disclosure restrictions also present a challenge to this approach. The USG would have to grant technology security and foreign disclosure approval to allow such collaboration with Canada.

Although a binational approach offers several benefits, it is also fraught with weaknesses and risks that would require considerable mitigation. To this end, an international transaction mechanism would serve as an acquisitions agreement between the United States and Canada. Canada relies on a requirement-setting and budgetary process which is fundamentally different than the USG's. To harmonize these diverse processes, the USG would need to fund a multi-year program or at least entire acquisition phases. This would be politically difficult but not unprecedented, as this was the approach used to acquire the JSF. This approach would require harmonization between DoD and the Canadian Department of National Defense (DND) to determine a common view of requirements and budget. They would also require a consensus on the Little A solution, agreeing on the requirements and the acquisitions approach.

The tumultuous US budgetary process poses significant programmatic risk to a binational acquisitions approach. However, astute negotiators can mitigate this risk by including provisions to balance budgetary shortfalls. This would provide the latitude for one nation to cover the other's budgetary gap one year, with the understanding this would be re-paid in subsequent years. This type of flexibility would reduce the risk of programmatic failure due to a single budgetary shortfall. The USG faces many difficult choices with respect to acquiring a CMDS. The requirements, budgeting, acquisitions approach, and binational options all present their own strengths, weaknesses, and risks. While much of this risk can be mitigated, choosing the correct approach will be essential to long-term programmatic success of a comprehensive CMDS.

Cruise missile engagement solutions

Regardless of whether the United States proceeds unilaterally or binationally, it must comprehensively address the F2T2EA kill chain to field an effective CMDS. Robust indications and warnings, C4I, early warning, target tracking, and engagement represent just a few links in this chain. Due to the emerging technologies uniquely suited for the engagement aspect of CMD, this thesis only analyzes technical solutions for the engagement element of the kill chain.

Ongoing CMD engagement initiatives

The United States is currently testing new CMD engagement alternatives. Most of these rely on kinetic engagement solutions. The first is the Joint Air Defense Operations-Homeland (JADO-H) which USNORTHCOM/NORAD tested in 2007. This concept would provide a rapidly deployable GBAD capability which can plug in with the standing Integrated Air Defense System (IADS). However, this system still relies on

kinetic GBAD systems and requires timely and actionable intelligence to effectively deploy. Regardless, this option would not be capable of protecting broad geographic areas and would not have time to react to a surprise cruise missile attack on the homeland.[41]

The USG is also considering the Low Cost Interceptor (LCI) which is designed to counter the cruise missile and asymmetric air threats. It would optimally provide 360 degree coverage of the United States utilizing numerous small missile silos spread across the borders and US coasts. LCI would rely on the JLENS as well as High Altitude Sensors (HAS) to detect inbound missiles.[42]

In 2006, Naval Post Graduate students utilized game theory analysis to score all three systems and found the LCI scored the highest because it met all the requirements to successfully engage cruise missile threats. Strengths of the LCI include no manning requirements at the individual sites, compatibility with all existing communication architecture, minimum number of silos required, and its ability to engage pop-up threats in only minutes. They recommended sustaining the Joint Air Defense Operations Center (JADOC) while pursuing JADO-H for the NSSE mission, but suggest strong consideration for the LCI concept to provide total US CMD.[43]

Directed energy technology

To date, the preponderance of CMD engagement capabilities have relied on kinetic technologies. Even modern initiatives such as the magnetic rail gun and hit-to-kill

[41] Dowling and Soria, 50.
[42] Ibid., 41-42.
[43] Ibid., 48.

missiles rely on hitting inbound cruise missiles with a projectile.[44] Although the Pk of these systems against inbound LACMs has increased, they are a limited resource which is difficult to deploy and costs hundreds of thousands of dollars per shot. Non-kinetic alternatives such as directed energy (DE) weapons may offer a more affordable and effective solution to CMD engagement.

Directed energy weapons are not an entirely new phenomenon. Greek historian Lucian recounts the first use of DE weapons by a general named Hippocrates. Applying an idea attributed to Archimedes, Hippocrates focused sunlight with mirrors to set fire to the sails of the Roman fleet during the siege of Syracuse in 212 BC.[45] Since then, man has developed several DE technologies which may be suitable for CMD. Laser and microwave are two such technologies which may be suitable for this application.

Lasers and microwaves are both comprised of electromagnetic radiation, but microwaves have a wavelength on the order of 10,000 times longer than lasers. Due to their different physical properties, both lasers and microwaves display distinct strengths and weaknesses when applied as DE weapons.[46] High-energy lasers (HELs) are comparable to a bolt-action sniper rifle, precise at longer range but only effective against one target. Conversely, high-power microwave (HPM) is more like a shotgun, covering a broader area at shorter range.

Laser power and range have increased exponentially, now able to reach hundreds of kilometers. They have demonstrated the ability to precisely target inbound artillery

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[44] Mike Conaway, "Enemy Cruise Missile, Meet the U.S. Rail Gun," *Wall Street Journal*, April 20, 2015, A.11.
[45] Doug Beason, *The E-Bomb: How America's New Directed Energy Weapons Will Change the Way Future Wars Will Be Fought* (Cambridge: De Capo Press, 2005), xi.
[46] Ibid., 23-24.

shells, mortars, and UAVs. Lasers are relatively inexpensive to operate, ranging from tens to thousands of dollars depending on the power required and fuel used. Lasers are also fast, travelling 150,000 times faster than a bullet.[47] They are highly effective against any projectile that contains explosives such as fuel or a warhead.

However, lasers demonstrate several challenges and weaknesses as DE weapons. Effective systems must provide beam control, target acquisition, tracking, beam stability, and beam shaping. Lasers must be narrowly focused, and therefore are only effective against one target at a time. Lasers also suffer from atmospheric attenuation which is prevalent at low altitudes. Lasers have advanced greatly in the past 50 years, and may be suitable for CMD against limited numbers of inbound LACMs. Unfortunately, defense spending on solid-state laser R&D has remained flat since fiscal year 2011.[48]

Unlike HEL, HPM can target a much broader area. They spread out on the order of 10,000 times more than lasers.[49] For this reason, HPM can simultaneously neutralize multiple targets within its field of view. High-power microwave is also effective against any target that contains electronic components. They do not rely on causing the target to structurally fail or explode; rather, they can simply disable guidance and navigation systems to bring down cruise missiles. Dr. Bill Baker of the Air Force Research Laboratory's DE Directorate claimed "The smarter the weapon, the dumber HPM can make it."[50] Microwave is also less susceptible to atmospheric attenuation than laser and therefore more effective in a coastal environment.

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[47] Ibid., 54-57.
[48] Dan Parsons, "Lasers Could Become Cost Effective Missile Defense Weapons," *National Defense*, August, 2014, 40.
[49] Beason, 57.
[50] Ibid., 183.

Although HPM enjoys many advantages over lasers, it also suffers from several limitations and challenges as a CMD DE weapon. Due to the rapid diffraction of HPM, its range is limited to approximately one kilometer. At this range an HPM weapon would have only five seconds to target an inbound LACM travelling at 500 mph. High-power microwave cannot simply overpower this range limitation because of what is known as the atmospheric breakdown limit. At high power levels, the microwave energy creates a plasma in the atmosphere which prevents its propagation entirely.

Another limitation of HPM is its sheer size. These systems require very large power sources to generate the megawatt-class power necessary for HPM DE weapons. The antennae themselves are also large, spanning at least 30 feet.[51] Despite these challenges, HPM systems may have application as CMD DE weapons where their size and limited range can be overcome.

Directed energy weapons systems

The USG has reinvigorated its investment in DE weapons systems. The USG recently awarded contracts of $22.6 million for developing the GBAD; the largest was to Raytheon which is designing a HEL. L-3 Corporation received a $6 million contract for the assembly which will aim the system and follow the designated target.[52] In 2015 the US Senate penned a provision to accelerate the fielding of technologies including DE weapons. The bill also added $20 million to the MDA's $30.3 million DE R&D request. The MDA is currently working with DARPA to develop various lasers for long-endurance UAVs which could target cruise missiles.[53]

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[51] Ibid.

[52] Parsons, 40.

[53] "Senate Panel's $400 Million Offset Fund Includes $200 Million for Directed Energy," *Space & Missile Defense Report*, June 8, 2015, 3.

Numerous weapons systems have already been tested or fielded which demonstrate the potential of the aforementioned technologies as DE weapons. General David Mann, Commander of JFCC IMD, testified before the SASC on a number of issues confronting his command. He cited the HEL Mobile Demonstrator (HEL MD), which is capable of firing 60 shots of a 50 kilowatt laser without recharging and is quite mobile. General Mann asserted the synergy of directed and kinetic energy systems has the potential to enhance homeland defense capabilities against cruise missiles.[54]

In 2007 the Air Force successfully tested its own chemical oxygen-iodine airborne laser mounted on a Boeing 747. Following a funding cut in 2010, then Secretary of Defense Robert Gates cancelled the program. The US Navy is investing in the Laser Weapons System (LAWS), which utilizes six lasers strapped together to create more powerful effects. In 2013, the US Navy successfully tested LAWS by shooting down a small drone. The Navy also employs a slab laser with a combined beam power of 105 kilowatts, but they are developing a system capable of more than 300 kilowatts.[55]

Although the USG has invested heavily in HEL, other countries have demonstrated increased interest in HPM weapons. The UK successfully tested an HPM weapon capable of targeting UAVs and cruise missiles as well as C4I and air defense assets. The UK tested the system aboard a BQ-145A drone on US ranges, leaving five of the airframes at the USAF UAV Battle Lab. Germany has also invested in HPM technology which can be mounted on a UAV.[56]

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[54] General David Mann, "Ballistic Missile Defense Programs in Review of the Defense Authorization Request for FY2016 and FYDP before the SASC," *Senate Armed Services Committee* (March 2015): 5.
[55] Parsons, 42.
[56] David A. Fulghum and Douglas Barrie, "U.K. Developing, Testing Directed Energy Weapon," *Aviation Week & Space Technology* Vol. 157, No. 5 (July 2002): 26.

However, it is not just US allies who are investing in DE weapons. The Russian defense industry has developed a DE weapon capable of disabling or destroying electronic systems in aircraft and precision-guided weapons. The system is also capable of disrupting GPS and satellite communications. Radio-Electronic Technologies Group, the weapon's developer, claims it can be employed on ground, air, and sea-based platforms. Russia commenced testing of the system at the end of 2015 and the US Counter Directed Energy Weapons (CDEW) program is researching ways to defend against such capabilities.[57] The research indicates many of the world's leading powers are developing increasingly capable DE weapons which may be suitable for CMD.

The analysis shows a geopolitical environment in which both state and non-state actors are demonstrating increasing capability and willingness to threaten the American homeland. Cruise missiles have advanced and proliferated at an alarming rate while NORAD has fallen behind in its capability to defend against them. The existing organizational construct for CMD is insufficient. There are numerous organizational, acquisitions, and technological options the USG may explore to effectively defend the homeland against cruise missiles.

[57] John Keller, "Russian Directed-Energy Weapon to Complicate Military Strategic Planning?," *Military & Aerospace Electronics* Vol. 26, No. 8 (August 2015): 2.

III. Recommendations

The preceding chapter described the state of cruise missile proliferation and technology within the context of the current geopolitical environment. The research examined the current state of US CMD organization and capabilities. Furthermore, it highlighted potential organizational, acquisitions, and technical solutions to implement a comprehensive CMDS. This chapter evaluates those various options and recommends an optimum approach while identifying the roles of specific stakeholders. These recommendations also consider the programmatic risks and offer steps to mitigate those risks whenever possible.

Organizational Solution

The optimal organizational solution is for the USG to expand the existing MDA's charter, authority, and budget to include the CMD mission. This option boasts less cost and programmatic risk than attempting to establish an entirely new CMDA. In this fiscally constrained political environment, it is extremely unlikely Congress and the President would authorize creation of an entirely new agency. The experience within the MDA and its ability to procure outside the JCIDS process make it the ideal organization to lead the US CMD enterprise.

To mitigate the political risk to this approach, stakeholders such as OSD, MDA, JIAMDO, USNORTHCOM/NORAD, and JFCC IMD must reach a consensus and collectively push for the expansion of the MDA's charter. The President must agree to expand the MDA's authorities and convince Congress to support this initiative. Congress must then sufficiently fund the MDA to fulfill its expanded CMD responsibilities. The

MDA must perform a thorough manpower study in accordance with the US Office of Personnel Management guidelines to determine the necessary personnel requirements.

Once established, the MDA must fully embrace its expanded role as the USG lead for CMD. To do this, the MDA must mitigate the likelihood of nepotism and institutional inertia by hiring the leading experts in the field of CMD. Furthermore, the MDA must integrate these CMD experts into the highest levels of leadership within the agency. It is essential the MDA does not relegate this new-found mission to a secondary status. Appropriate oversight by Congress will be essential to ensure this does not happen. Once fully implemented, the MDA should lead CMD efforts with the same commitment with which it has led BMD efforts.

Acquisitions Solution

The USG should adopt a time-phased acquisitions approach for the short and long-term acquisition of a comprehensive CMDS in conjunction with Canada. In the short-term (less than three years), OSD should continue to serve as an ad hoc coordination point for CMD acquisitions. USNORTHCOM/NORAD should continue to lead integration of existing CMD weapons systems and technologies to mitigate gaps in NORAD CMD capabilities.

USNORTHCOM should sponsor a JCTD to fulfill the Big A requirement toward a comprehensive CMDS. This approach will avoid the programmatic risk associated with a JCIDS program of record initiated by a single service. Furthermore, USNORTHCOM should leverage DARPA and the MDA's ongoing S&T-funded efforts to develop new CMD technologies.

To formalize the binational approach, the USG must take the appropriate diplomatic steps necessary to include Canada in the earliest stages. The USG must also issue technical security and foreign disclosure approval to enable this binational coordination. The United States and Canada must agree on an international transaction mechanism which will facilitate a binational acquisitions process and minimize budgetary risk to the program.

In the long-term (three to ten years), the newly empowered MDA should take over the leadership role in development and acquisition of a comprehensive CMDS for NORAD. Leveraging its unique budgetary authority, the MDA should establish a CMDS program of record outside the normal JCIDS process. To fulfill the Little A acquisitions requirement, the MDA should lead a comprehensive AOA to evaluate a mix of COTS technologies and an RFP which leverages the advances made by DARPA and industry. The MDA should establish a Program Manager responsible for ensuring a comprehensive CMDS with a target IOC of 2025.

Technological Solution

At the unclassified level, this thesis offers only broad recommendations on potential technical solutions for CMD defense. The exact means, tactics, techniques, and procedures are beyond the scope and classification of this research. Generally speaking, NORAD must rely on a combination of existing kinetic CMD systems while fielding newer non-kinetic systems to complement them. These engagement systems must be linked seamlessly with a C4I network which can leverage early warning and tracking systems across the entire NORAD area of responsibility.

NORAD should employ the JADO-H concept in conjunction with existing GBAD capabilities within the IADS. NORAD must also leverage improved kinetic CMD systems as well as non-kinetic means which are optimized based on their capabilities and limitations. To sufficiently defend the homeland from waves of cruise missiles, NORAD must field a CMDS which employs a layered defense. This layered defense should extend from the approaches to the high-value targets within the United States and Canada. NORAD should continue to field sensors such as JLENS to provide necessary early warning and detection approaching the Air Defense Intercept Zone (ADIZ).

NORAD should strongly consider the use of HPM systems to engage cruise missiles in the coastal approaches. The large antennae for these microwave systems could be placed off shore in a manner similar to oil platforms. Their substantial power systems could remain on shore for ease of maintenance and protection while running power cables along the ocean floor to the antennae. Microwave systems could also be placed in the outskirts of population centers. These HPM systems would serve as proverbial shotguns to target numerous cruise missiles as they approach high-value targets. They are ideally suited for targeting multiple threats at close range with very little advanced warning.

NORAD should examine lasers to serve as proverbial sniper rifles to target any threats which slipped past the initial screen of HPM systems. As a land-based system, these HELs would face far fewer complications related to size, fuel, stability, and targeting than mobile laser systems. NORAD should also field the LCI system of missile silos as a last line of defense against LACMs which make it past the DE systems. These silos should be most concentrated near population centers and high-value targets.

Conventional kinetic systems such as manned fighters, Patriot, and AEGIS should continue to train to their NORAD CMD missions. These are ideally suited for deployment when there are advanced indications and warnings of potential threats. They should be deployed in these situations to protect the most high-value targets. To protect the homeland from a wave of cruise missiles, NORAD must field a layered CMDS which leverages emerging non-kinetic DE systems in concert with legacy kinetic systems.

The preceding recommendations represent an approach to inform further research into the matter of homeland CMD. They do not constitute the final solution; rather, they aid in setting an agenda which will facilitate this end. Further research at the classified level is certainly necessary to distill solutions with the necessary fidelity. Experts in each particular discipline should investigate further to clarify the optimum approach toward a comprehensive CMDS to protect the homeland.

IV. Conclusions

The world has become an increasingly dangerous place. The geopolitical environment is comprised of state and non-state actors who wish to expand their power and influence. Some of them wish harm upon the United States and Canada. The NORAD region no longer enjoys the relative isolation afforded by two vast oceans. Land attack cruise missiles represent a substantial threat to the United States and Canadian homeland. The increasing proliferation, accuracy, lethality, and ease of employment of these systems presents a significant challenge to NORAD defenses. A wave attack of these weapons against the homeland could not be effectively repelled by NORAD's current air defense systems.

The USG has invested heavily in BMD capability while largely turning a blind eye to the LACM threat. The USG has supported ballistic missile nonproliferation treaties which have yielded the unintended consequence of increased cruise missile proliferation. Although the Bush administration changed the name of the Ballistic Missile Defense Organization to MDA, it has not risen to the calling of its new name. The USG must empower and fund the MDA to be a true torchbearer for CMD.

The MDA should pursue the recommended acquisitions process to develop and field a comprehensive CMDS. This system should employ a layered defense which begins with HPM weapons in the approaches to the NORAD ADIZ and HEL systems on the coasts and border. This should be integrated with kinetic systems such as the LCI, manned fighters, Patriot, and Aegis to protect population centers and high-value targets. Collectively, these engagement systems must be fully integrated into a command and control architecture with robust early warning and target acquisition capabilities.

The United States and Canada must act soon. Those who wish harm upon them are growing increasingly bold and aggressive in their tactics. They will continue to find weaknesses in the defense of the homeland which are vulnerable to asymmetric attack. The USG must not wait until a terrorist organization launches a wave of anthrax-laden cruise missiles against the homeland to develop a comprehensive CMDS. Furthermore, the USG simply cannot wait for a near-peer competitor to threaten the homeland with conventional cruise missiles in order to weaken American resolve in a crisis. Defense of the homeland is the most sacred and fundamental responsibility born by any government. If the United States and Canada do not act soon to shore up NORAD's defenses against cruise missiles, the American people may pay the ultimate price.

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Vita

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